Creating a Standards Framework for Sustainable Industrial Energy Efficiency

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Abstract

Industrial motor-driven systems consume more than 70% of global manufacturing electricity annually and offer one of the largest opportunities for energy savings. Program experiences in the US, the United Kingdom, and China have demonstrated that energy savings opportunities are typically 20% or more for these systems across all industrial sectors.

Despite the potential benefits, energy savings from motor-driven systems have remained largely unrealized worldwide. Both markets and policy makers tend to focus on system components, which have a typical improvement potential of 2-5% versus 20-50% for systems. Determining how to optimize a system requires a high level of technical skill. In addition, once an energy efficiency project is completed, the energy savings are often not sustained due to changes in personnel and production processes. Although training and educational programs to promote system optimization have proven effective, these resource-intensive efforts have only reached a small portion of the market.

The same factors that make it so challenging to achieve and sustain energy efficiency in motor-driven systems (complexity, frequent changes) apply to the production processes that they support. Yet production processes typically operate within a narrow band of acceptable performance. These processes are frequently incorporated into ISO 9000/14000 quality and environmental management systems, which require regular, independent audits to maintain ISO certification, an attractive value for international trade.

This paper presents a new approach to achieving industrial system efficiency (motors and steam) by creating a top-down and bottom-up framework that will encourage plants to incorporate system energy efficiency into their existing ISO management systems. We will describe the Industrial Systems Framework, which is being prepared for China, but applicable elsewhere, that includes national standards a*nd an Industrial Systems Optimization Library*. ISO work instructions are part of the framework, so that a plant can easily incorporate projects into their ISO Quality Environmental Manual. The goal is to provide a plant-based mechanism that helps each company maintain their focus on energy efficiency commitments, provide visibility for its achievements, and provide verification of results for financial backers (including carbon traders) to help stimulate much greater industrial energy efficiency.

1 Introduction

Industrial motor-driven systems consume more than 70% of global manufacturing electricity annually[1] and offer one of the largest opportunities for energy savings. The energy savings potential from motor-driven systems (as well as other industrial systems,

[1] 2194 billion kWh annually based on analysis conducted by Lawrence Berkeley National Laboratory, Alliance to Save Energy, and Energetics July 2004

such as steam) remains largely unrealized worldwide. Both markets and policy makers tend to focus on individual system components, which have a typical improvement potential of 2-5% versus 20-50% for complete systems, as documented by program experiences in the U.S., U.K., and China.[2]

Several factors contribute to this situation, including the complexity of these systems and the institutional structures within which they operate. Industrial motor-driven systems are ubiquitous in the manufacturing environment, but their applications are highly varied. System optimization cannot be achieved through component standards or labeling or “one size fits all” approaches. The presence of energy-efficient components, while important, provides no assurance that a motor-driven system will be energy-efficient. In fact, the misapplication of energy-efficient equipment in industrial motor systems is common. The disappointing results from these misapplications can provide a serious disincentive for any subsequent effort toward system optimization.

System optimization requires taking a step back to determine what work (process temperature maintained, production task performed, etc) needs to be performed. Only when these objectives have been identified can analysis be conducted to determine how best to achieve them in the most energy-efficient and cost-effective manner.

The skills require to optimize systems are readily transferable to any individual with existing knowledge of basic engineering principles and industrial operations. Training and educational programs in the US and the UK have successful transferred system optimization skills since the early-1990s. A recent United Nations Industrial Development Organization (UNIDO) pilot program in China demonstrated that a concentrated training program could successfully transfer these skills across language and cultural barriers (Peters and Nadel). Although effective, training to adequately prepare an individual to conduct system optimization assessments is resource-intensive and best suited to developing a small cadre of skilled professionals to work with plant personnel.

Once the importance of optimizing a system and identify system optimization projects is understood, plant engineering and operations staff frequently experience difficulty in achieving management support. The reasons for this are many, but central among them are two: 1) a management focus on production as the core activity, not energy efficiency and 2) the existence of a budgetary disconnect in industrial facility management between capital projects (incl. equipment purchases) and operating expenses. As a further complication, experience has shown that most optimized systems lose their initial efficiency gains over time due to personnel and production changes. Since system optimization knowledge typically resides with an individual who has received training, detailed operating instructions are not integrated with quality control and production management systems.

One of the most tested mechanisms used to promote energy efficiency and market transformation requires the application of energy efficiency standards. However, this paper proposes system standards, not equipment component standards. Moreover, the

2 US- Motor Challenge, BestPractices; UK- Best Practice Programme, Motor Challenge; China Motor System Energy Conservation Program

system that we are describing extends beyond the motor-driven system to the management system, and builds industrial energy efficiency from both a top-down and a bottom-up approach.

Since production is the core function of most industrial facilities, it follows that the most sophisticated management strategies would be applied to these highly complex processes. Successful production processes are consistent, adaptable, resource efficient, and continually improving- the very qualities that would support industrial system optimization. Because production processes have the attention of upper management, the budgetary disconnect between capital and operating budgets is less evident. Unfortunately, efficient use of energy is typically not addressed in these management systems in the same way as other resources such as labor and materials. We feel that the answer lies in fully integrating energy efficiency into these existing management systems.

A number of management systems are currently used by industrial facilities across most sectors to maintain and improve production quality. We have selected ISO as the management system of choice for further study because it has been widely adopted in many countries, is used internationally as a trade facilitation mechanism, is already accepted as a principal source for standards related to the performance of energy-consuming industrial equipment, and has a well-established system of independent auditors to assure compliance and maintain certification. For the purpose of this discussion, ISO includes both the quality management program (ISO 9001:2000) and the environmental management program (ISO 14001), which can share a single auditing system.

This paper proposes a link between ISO 9000/14000 quality and environmental management systems and industrial system optimization that is based on the creation of a framework. This *industrial standards framework* includes energy efficiency standards, policies, training, and tools that have the net effect of making system optimization for energy efficiency as much a part of typical industrial operating practices as waste reduction and inventory management. The objective is a permanent change in corporate culture using the structure, language, and accountability of the existing ISO management structure. This is market transformation primarily from the inside out. A proposed standards framework for China will be presented in detail, but most elements of this approach would be equally applicable in other industrialized or industrializing countries.

2 Background

2.1 ISO Quality and Environmental Management Systems

The operation of industrial motor systems can have a significant environmental impact on an organization. Inefficient systems not only use up to twice the energy required of optimized systems, but are also responsible for off-quality products, waste and scrap. Organizations do not normally recognize this impact. The rework of off-quality products resulting from improperly operating systems can double the energy input of a product and produce additional waste. Products that cannot be reworked result in increases in the amount of scrap requiring disposal. Properly operating systems not only have reduced energy input requirements, but in many cases, reduce other energy inputs in the tools and equipment being operated by the system.

Most energy audits of such systems result in recommendations that apply to the current factory production levels. In cases where future expansion is anticipated at the time of the audit, the expansion is commonly included in the recommendations. After the recommendations have been implemented and the auditor is gone, there is no procedure in place to ensure continued proper operation of the system. Often, improvements in motor systems are made but changes to production levels and/or personnel negate the improvements over time. In other cases, operating personnel simply go back to doing things the way they were doing them, again negating the improvements.

In order to ensure persistence for energy efficiency savings from system optimization projects, a method of verifying the on-going energy savings under a variety of operating conditions must be developed. This method must ensure that changes that could affect the operating characteristics of the motor system are analyzed in light of the new operating paradigm for that system. A vehicle exists for continuously monitoring an organization's adherence to the new motor system operating paradigm. That vehicle is the ISO 9000/14000 Series Standards.

The purpose of ISO 14001 is to provide a framework for organizations to achieve and demonstrate their commitment to an environmental management system that minimizes the impact of their activities on the environment (a similar framework for ISO 9001:2000 pertains to quality). The framework does not include any specific requirements, only a means of achieving goals set by the organization. This ISO standard also provides for an audit procedure to verify that established policies of the organization are being followed. To maintain certification, participating companies must maintain a Quality Environmental Management (QEM) Manual.

The environmental management system model for this standard is composed of six elements:

1. The establishment of an environmental policy by the organization
2. Planning
3. Implementation and operation
4. Checking and corrective action
5. Management review
6. Continual improvement

Once top management has defined the organization's environmental policy, the next step is planning. In the ISO 14001-1996 Environmental management systems – Specification with guidance for use, Section 4.3.1 states:

The organization shall establish and maintain (a) procedure(s) to identify the environmental aspects of its activities, products or services that it can control and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment. The organization shall ensure that the aspects related to these significant impacts are considered in setting its environmental objectives.

There are two approaches to establishing and maintaining efficient operation of motor systems. Both approaches involve the “Planning” phase and the “Implementation and operation” phase of ISO 14001. For operations that are ISO 9000 certified, but not ISO 14000, these same steps can be incorporated into the ISO 9000 Quality Standards.

First, a set of best practices standards can be developed in the ISO format that can be incorporated in the “Planning” portion of ISO 14001. From those standards, work instructions can be written for the “Implementation and operation” portion. By making these “best practices” standards part of ISO certification, an organization ensures that these best practices will become part of the organization culture through the continuing audit procedure required by ISO. By making these best practices ISO-friendly, organizations can easily incorporate them into existing ISO systems. The number of standards incorporated can be determined by the individual organization. As more goals are reached, new standards can be included, further improving the energy efficiency of the motor systems’ operation and making efficiency part of the culture. Second, for organizations that are involved in carbon financing, ISO standards can be developed that are specific to that organization’s on-going commitment to energy efficiency and pollution reduction. These standards can be developed by the entity conducting the energy efficiency audit on a motor system, or they can be copied from the *System Optimization Library* and modified to fit individual requirements.

2.2 A Brief Primer on ISO Terminology

As described in this paper, a procedure refers to a general description of a process and is incorporated into a company’s QEM Manual.

The first step is for a company to develop a policy of efficient operation of motor-driven systems within their facility, then develop and implement system procedures that are consistent with that policy:

- The company must develop procedures for motor-driven systems;
- The company must document those procedures and keep the documentation up to date;
- Each procedure should specify its purpose and intended scope, and
- Procedures may also refer to detailed work instructions that explain exactly how the work should be performed.

A project refers to a specific activity designed to contribute to meeting the ISO requirement for continuous improvement. Examples of projects include: initiating a leak management program or replacing a throttle valve on a pumping system with a speed control device. Work instructions are step-by-step information (text, diagrams, photos, specifications, etc) to assist operations staff in maintaining the improvements realized through implementation of a project. Examples include: instructions on how and when to check leaks and repair them or maintenance information to ensure that the pump system speed control device continues to function efficiently. Work instructions are typically posted for or easily accessible to operations staff.

The next section presents the basic elements of an industrial standards framework, followed by a model for implementation of the framework in China that links it to ISO quality and environmental management programs.

3 Elements of an Industrial Standards Framework

The basic elements of an industrial standards framework include energy efficiency standards, policies, training, and tools. The purpose of the framework is to standardize, measure, and recognize industrial system optimization efforts. The framework builds on existing knowledge of “best practices” using commercially available technologies and well-tested engineering principles. The framework seeks to engineer industrial systems for reliability and productivity, as well as energy efficiency. Factories can use the framework to approach system optimization incrementally in a way that maximizes positive results and minimizes risk and downtime. Table 1 provides a listing of these elements, their purpose, and relative importance in the overall scheme.

A key element of the framework is a corporate energy management program. Since ISO currently has no explicit program for energy efficiency, the framework builds energy efficiency into an ISO continuous improvement program (9001:2000 or 14001) through an ISO-compatible energy management program. The corporate energy management program that seems to offer the most straightforward, publicly accessible, ISO-friendly approach is the American National Standards Institute Management System for Energy (ANSI/MSE 2000) developed by Georgia Institute of Technology. This standard is also compatible with Energy Star Guidelines for Energy Management.

ANSI/MSE 2000 was developed by individuals with experience with ISO certification and is quite suited for future consideration as an ISO standard. Formal integration of energy efficiency into the ISO program certification structure (most likely as part of the ISO 14000 series), while desirable for the explicit recognition of energy efficiency as an integral part of continuous improvement, would be a resource- and time-intensive undertaking. Since the current ISO program structure creates no specific barriers to the inclusion of energy efficiency projects, immediate program integration is not a high priority. Instead, the Industrial Standards Framework recommends the use and further testing of ANSI/MSE 2000 in multiple countries with the long-term goal of seeking ISO recognition.

The Chinese government has expressed interest in adapting ANSI/MSE 2000 as a standard for China and has had it translated for further study.

3.1 Industrial Systems Optimization Library

The Industrial Systems Optimization Library (Library) is a series of Word documents organized via an extensive table of contents and guidelines. To effectively use the

Table 1. Elements of an Industrial Standard Framework

Element	Category	Purpose	Current Status	Importance	Compatibility
Corporate Energy Management Standard	Standard-Voluntary or Mandatory	Provides organizational guidance for “hardwiring” energy management into company management practices.	ANSI/MSE 2000 (US); adaptation planned for China	Essential for management support; compliance w/standard can be met through other elements	Written as possible ISO standard w/ ISO-friendly documentation and continuous improvement requirements
	Training	Prepares management to implement standard	Existing training through Georgia Tech (US)		
Motor System Standards	Standard-Voluntary or Mandatory	Sets efficiency goals for motor systems enforceable through periodic measurement & application of best practices	Standards GB/T 13466 & GB/T 12497 (China). Note: China also has a mandatory Motor Efficiency Standard GB 18613-2002	Very helpful-broadly establishes system efficiency goals	References Energy Management Standard; designed to be used with Library
	Training	Prepares factories to comply w/standard	Training to be developed through CNIS (China)		
System Optimization Library	Tool-Electronic reference document	Provides factory personnel and experts w/guidance on system optimization within the ISO context of procedures, projects, & work instructions	Library samples developed & reviewed; demonstration project planned (China)	Essential-provides an incremental path to continuously improve and maintain system efficiency	Written in ISO language for use in ISO 9000 or 14000 program; supports corporate energy management goals
	Training	Prepares factory personnel and system optimization experts to use Library (follows system optimization awareness training)	Training to be developed as part of demonstration project (China)		
System Optimization Training	Training	Expert training prepares a cadre of engineers to conduct factory assessments, train factory personnel, & assist in project development Awareness training alerts factory personnel to system optimization opportunities	Expert & awareness training developed as part of UNIDO Motor System Program (China)	Essential-provides the technical skills for small group of experts and prepares them to train others	Consistent with the approach used for Motor System Standard, System Optimization Library
ISO 9001:2000 and/or 14001 certification	Independent Certification	Determines whether a factory is meeting ISO objectives for continuous improvement via procedures, projects, & work Instructions	Global program with >500,000 participating companies	Essential for sustaining & improving energy efficiency	Other elements provide path for maintaining certification
Energy efficiency targets by industrial sector	Policy	Provides plant-specific energy efficiency targets based on continuous improvement that is non-prescriptive and developed in cooperation with the industrial sector	Pilot program developed and demonstrated in Chinese steel industry; based on European experience	Very helpful-engages management in efficiency objectives, leading to other elements	Compatible with all elements
Government Recognition of Outstanding Energy Management	Policy	Provides meaningful recognition program for factories who initiate and sustain continuous improvement for energy efficiency	Proposed for China	Very helpful for motivating companies to become energy efficient	Recognition based on measurable results from other elements

Library, the user needs to be familiar with the system optimization approach (awareness level training) but does not need to become a system optimization expert. Training on use of the Library requires a much smaller time investment than that required for a systems optimization expert. This approach is designed to the “80/20” rule for achieving persistent energy savings in systems of moderate complexity. For highly complex systems, or for those who seek to achieve full optimization, the assistance of a highly trained system optimization expert is recommended.

The Library provides the user with guidance concerning how to approach implementation of an energy efficiency project once an opportunity has been recognized. It is designed to support an incremental approach to optimization, by providing a logical sequence of energy efficiency projects that build on each other until the targeted performance is obtained. A company can decide how quickly to proceed with optimization and on which systems. The most critical element of the Library is the work instructions, which provide written documentation that “hardwires” a new project or procedure into standard management practices. Once a set of work instructions has been integrated, operational deviations from these instructions (such as to returning to former inefficient practices) are a path of most, rather than least, resistance. If the company is ISO certified, deviations from work instructions without a well-documented and supported reason attract negative attention and management notice.

The proposed Library will require about eighteen months to develop and an equal time period to test it in industrial facilities. A demonstration project is proposed for Shanghai and Jiangsu, which have a large number of ISO facilities and trained system optimization experts

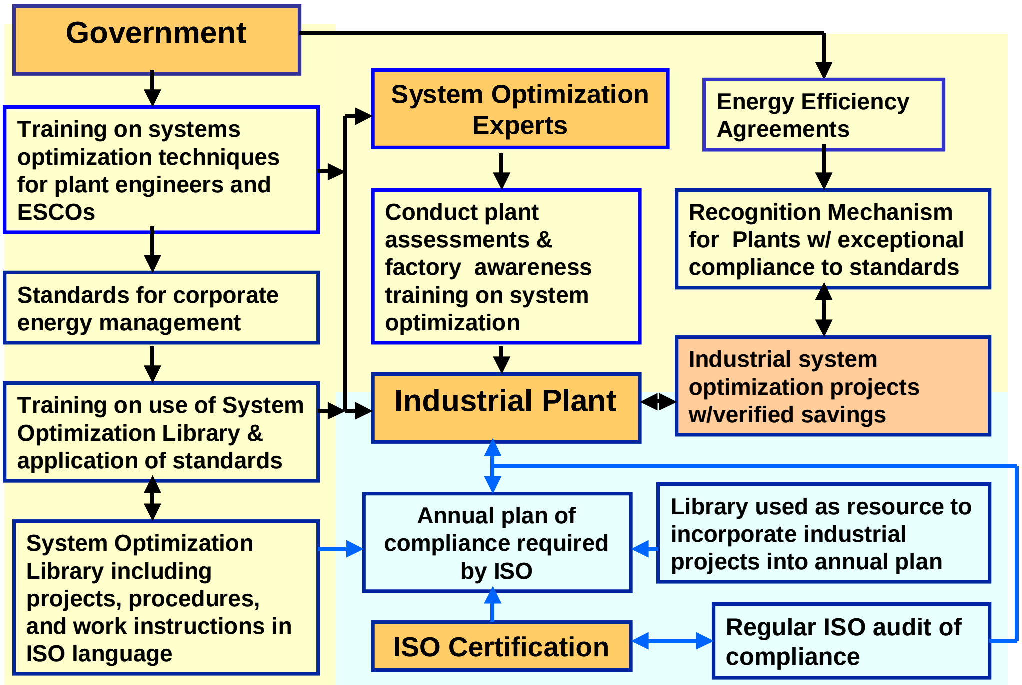
4 Establishing an Industrial Standards Framework in China

Industrial motor systems are a major user of electricity in China, accounting for more than 50% of overall electricity use. Optimizing half of these motor systems would achieve a 20% average energy savings (a reasonable long-term goal). This would save the equivalent of more than US$4 billion annually and reduce carbon emissions by more than 25 MMT annually.

Through a combination of standards, tools, and training, the Industrial Standards Framework seeks to make energy efficiency an integral part of corporate management systems, with a special emphasis on ISO as the principal international management system. ISO certification has now become a significant trade facilitation vehicle for developing countries- for example; China leads the world in growth in the number of new certifications with approximately 100,000 certificates issued through December 2003 (ISO Survey 2004).

The proposed Industrial Standards Framework in China would build on both the skills developed in Jiangsu and Shanghai through the UNIDO pilot program (Williams, et al 2005), government interest and support for energy efficiency standards and industrial energy efficiency in general, and the prevalence of ISO-certified plants in China.

Figure 2: Overview of the Industrial Standards Framework



4.1 The Role of Government

The primary role of government in the Framework is to develop and issue energy efficiency standards and to support the provision to industry, consultants, and suppliers of training and tools to aid in compliance. A further role is to recognize outstanding efforts that exceed compliance requirements.

Standards for corporate energy management provide a framework for companies to integrate an energy efficiency ethic into their management practices. Government-sponsored training prepares plant engineers and emerging energy service companies with:

- The skills to recognize energy efficiency opportunities via training on system optimization techniques;
- An understanding of standards requirements;
- Knowledge and access to the System Optimization Library for use in developing and implementing projects; and
- Government-sponsored recognition based on verified energy savings provides industrial plants with the incentive to document and report project savings.

4.2 The Role of System Optimization Experts

Engineers (plant-based and consulting) are trained following the model developed in the UNIDO China Motors Program by of team of international experts and the most skilled practitioners from the first group of experts trained through the UNIDO program. This group of experts will be expected to: provide awareness training to encourage plants to undertake system optimization improvements; conduct plant assessments to identify system optimization opportunities; work with plants to finance and develop projects based on these findings; and prepare case studies of successful projects. This cadre of experts will also form the nucleus for future training of additional experts.

4.3 The Role of Industrial Plants

Industrial plants are responsible for compliance with national standards for corporate energy management, which typically require:

- an energy management team led by an energy coordinator with strong management support;
- policies and procedures to promote energy efficiency;
- projects to demonstrate continuous improvement in energy efficiency; and
- monitoring and measurement to document achievement of annual energy efficiency goals.

These requirements can be achieved through: the application of system optimization techniques (with their own staff or outside experts) to identify energy efficiency opportunities; and use of the System Optimization Library to develop and document projects and work instructions in ISO-compatible (also MSE 2000-compatible) language.

If the industrial plant is ISO-certified, the System Optimization Library can be used as a resource to incorporate includes new work instructions, projects and procedures into their current ISO 9000/14000 program. The periodic ISO audit provides independent verification of compliance with written procedures and policies and energy-efficient operation becomes part of the factory culture.

5 Conclusion

Industrial motor system optimization offers great potential for energy savings that is largely unrealized. Training alone, while essential for creating the awareness and skills required to identify potential projects, is insufficient to ensure the persistence of energy savings once these projects are implemented. What is needed is a framework that introduces a standardized approach to system optimization that includes measurement, documentation, and ongoing work instructions. The existing ISO quality and environmental management programs provide an effective foundation for this framework that is international in scope, relevant to both industrialized and industrializing countries, and already incorporates documentation, continuous improvement, and independent verification requirements. Since these programs are already part of the “language of management” and are widely accepted, the inclusion of system optimization practices becomes just one more aspect of an ongoing effort, rather than something new and resource-intensive to implement.

A framework that employs training, implementation of standards for efficient operation of energy systems, and integration of system optimization practices into a company's existing operating paradigm will result in sustainable energy efficiency. A program based on this framework can be delivered in selected countries where energy and fuel prices demand attention to energy efficiency and where governments are supportive of using standards to upgrade environmental and energy management practices. China offers particularly fertile ground to demonstrate these concepts, because of its support for energy efficiency standards, problems with adequate electrical supply, and large number (100,000) of ISO-certified industrial facilities.

Following demonstration of the successful application of energy efficiency standards in China and several other countries, national standards authorities from these countries may wish to approach ISO with a view to integration of energy systems optimization into international standards regimes.

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